QUANTUM SPACE-TIME TRANSFORMATIONS AND REFERENCE FRAMES STATES

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Abstract

We argue that correct account of the quantum properties of macroscopic objects which form reference frames (RF) demand the change of the standard space-time picture accepted in Quantum Mechanics. Galilean or Lorentz space-time transformations are shown to become incorrect in this case and for the description of transformations between different RF the special quantum space-time transformations are introduced. Consequently it results in the generalised Schrodinger equation which depends on the observer mass. The experiments with macroscopic coherent states are proposed in which this effects can be tested.

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1 Introduction

In a modern Quantum Mechanics (QM) the particles states and other objects evolve in Minkowski space-time regarded as independently existing entity. Alternatively it's the main method of the description of the surrounding world from the point of view of particular observer. In Classical Physics it corresponds to introduction of space coordinate axes associated with particular reference frame(RF) which is supposed to be some solid macroscopic object of nonzero mass or the system of them. Despite that in QM the behavior of physical objects can be strikingly nonclassical it's tacitly assumed describing RF properties in QM that any RF evolution is always exactly classical. Consequently all RF coordinate transformations in QM are supposed to be identical to classical - Galilean or Lorentzian ones. In our paper we argue that this assumption is in general incorrect and quantum features of RF should result in a special quantum space-time transformations. We must stress that this results will be obtained without introducing new axioms or hypothesys ,but staying in the framework of standard QM. In our opinion current discussions of Quantum space-time should include the correct definition of quantum RF [1] First the importance of RF quantum properties was noticed in Quantum Gravity study of distributed - dust or fluid RF [2], [3]. Yet their detailed analysis even for flat space-time concerned with Quantum Measurements aspects wasn't performed up to now, only some phenomenological discussions were published [4].

In this paper only one quantum RF effect will be analysed. Namely it's the predicted by QM existence of the wave packet of the macroscopic object defined as RF, which gradually enlarge with time. Despite that its scale in the standard laboratory conditions is quite small ,we obtain that it can have important meaning both for Cosmology and for small (up to Plank scale) distance Physics. It'll be shown that in nonrelativistic QM quantum RF transformations corresponds to the additional quantum symmetry. We descibe also the special experiments which can be proposed to test this conclusions using modern experimental technics.

The formulated problem is closely related to the macroscopic quantum coherence topics which embrace different observations of the superpositions of the macroscopic objects states. The recent studies have shown that for low dissipation superconductor systems the superpositions of the macroscopic states can be observed [5]. The experimental tests of this effects with SQUID rings are now prepared [6].

In distinction from Classical Physics in QM framework the system defined as RF presumely should be able to measure the obsevables of quantum states i.e. to be quantum observer. At first sight it seems this problem can be solved only when the detailed microscopic model of state vector collapse will be developed. Despite multiple proposals up to now well established theory of collapse which answer all difficult questions is absent [7]. Alternatively we'll show that our problem premises doesn't connected directly with the state vector collapse description [12]. In place of it we'll make two simple assumptions on the observer system properties , which are in the same time rather weak. The first one is that the observer system (OS) or RF consists of the finite number of atoms and have the finite mass. It was argued recently that even interaction with the single atom can result in the collapse of

particle wave function , which seems to us quite sensible [9].

So in this paper we assume that observer system (OS) is the ensemble of microparicle detectors , meters and recording devices which perform the coordinate or other measurements on quantum objects. As the realistic example we can regard photoemulsion plate or diamond crystall which can measure microparticle position relative to its c.m. and simultaneously record it. We'll regard measuring device to be in a pure state as usually made in a Measurement Theory.

The experiments with the atomic and molecular beams confirm that complex quantum system can be obtained in delocalised state without change of its internal properties. We'll consider the hypothetical situation when the free observer O_1 is described by some other macroscopic observer O_M as a pure quantum state with large uncertainty of centre of mass coordinate $R_c = \sum m_i * r_i/M$. The question which we had in mind preparing this work was : if the observer can be in such delocalised quantum state what will he see looking at the objects of our macroscopic world ?

It's well known that solution of Shrodinger equation for any free quantum system in a pure state consisting of N constituents can be presented as the

$$\Psi(r_1, ..., r_n, t) = \sum c_l \Phi_l^c(R_c, t) * \phi_l(r_{i,j}, t) \tag{1}$$

where $r_{i,j} = r_i - r_j$ are internal coordinates of constituents [10]. Here Φ_l^c describes the c.m. motion of the system. It demonstrates that in QM framework the functioning and evolution of the system in the absence of the external fields is separated into the external evolution as whole of the pointlike particle M and internal evolution completely defined by $\phi_i(r_{i,j}, t)$ if constituents interaction depends only on r_{ij} as usually have place. So the internal evolution is independent of whether the system is localised in macroscopic reference frame (MRF) or not. Relativistic QM and Field Theory studies show that the factorisation of c.m. and relative motion holds true even for nonpotential forces and variable N in secondary quantised systems [8]. Moreover this factorisation expected to be correct for nonrelativistic systems where binding energy is much less then its mass m_1, which is characteristic for most of real detectors. For our problem it's enough to assume the factorisation of c.m. motion holds for the observer system only in the time interval T from the system preparation procedure , until the act of measurement starts ,i.e. when measured particle collides with it. More exactly our second and last assumption about observer properties is that the during period T its state is decribed by the wave function generalising (1) of the form

$$\Psi(R_c, q, t) = \sum c_l \Phi_l^c(R_c, t) * \phi_l(q, t)$$

where q denote all internal detector degrees of freedom which evolve during T according to Schrodinger equation. To simplify our calculations we'll take below all $c_j = 0$ except c_1 which wouldn't influence our final results.

Any free object which was initially localised in a wave packet $\Phi(R, t_0)$ after it will gradually smear in space at a low speed ,which for gaussian packet with initial dispersion a_0 described as [10] :

$$a(t) = (\int (R - \bar{R})^2 |\Phi(R, t)|^2 d^3R)^{1/2} = a_0(1 + \frac{t^2}{m^2 a_0^4})^{1/2} \tag{2}$$

(Plank constant $\hbar$ and c in our calculations is equal 1). The standard conclusion is that to observe experimentally measurable smearing of macroscopic object demands too large time , but we'll show that for some mesascopic experiments it can be reasonably small to be tested in the laboratory conditions. In our work it's permitted ad hoc preparation of any initial state vector described by the smooth function $\Psi(r_i, t_0)$ in agreement with QM postulates. During this study we assume that RF and OS are always identical entities, but we'll discuss their possible distinctions in conclusion which in fact can weaken demands to RF formulated in this chapter.

2 Q-transformations Formalism

To explain our approach to RF transformations in QM in a simpliest terms we consider gedankenexperiment (GEO) in which wave packet of observer system O can be studied. Its layout where gravitation force is absent includes collimated along the Z axe neutron source S_n installed inside vacuum chamber and O suspended in its volume without any contact with the walls . S_n can emit one by one well-timed neutrons with mass m_2 in a very narrow beam with coordinates x_s ,y_s, so that their wave function $\psi_n(x_n)$ can be approximated by the delta-function $\delta(x_n - x_s)$. All states are considered at fixed time t_0 and due to t dependence in ψ arguments omitted , until evolution isn't become essential. For the simplicity the wave packet of the free observer O is supposed to smear significantly only along X axe and described by the wave function $\psi_1(x_1)$ (internal wave functions can be neglected as we argued). All this wave functions are defined in MRF connected with some macroscopic object M_R which mass m_0 is very large and in this example is taken to be infinite. We suppose that O with total mass m_1 includes detector D_o at the distance d_d from c.m. and small (pointlike) aperture δw so that D_0 internal wave function relative to O C.M. is : $\phi_d(x'_d) = \delta(x'_d - d_d)$. Additional neutron detector D_2 is installed on the opposite chamber wall and detect the neutrons which didn't interact with D_o.

Due to independence which means the factorisation of O and n states according to the form (1) n wave function in ORF ψ' can be extracted from the $O + n$ system wave function:

$$\psi(x_n, x_1) = \psi_1(x_1)\psi_n(x_n) = \Phi_c(X_c)\psi'_n(x_n - x_1) = \psi_1(\frac{m_1 x_1 + m_n x_n}{m_1 + m_n})\psi_1(x_n - x_1 - x_s) \quad (3)$$

Function Φ describes the state of this system as the whole and can't be found by no mesurement of n in ORF. ψ_n in fact put constraint on its state and results in its correlation with ψ'_n. Considering the collapse in different RF we note that O and MRF observers will treat the same event unambiguously as the n detection (or it flight through D_0). In observer reference frame (ORF) it reveals itself by the detection and amplification process in D_o initiated by n absorption and recorded later in RD. For MRF the collapse results from the nonobservation of neutron in a due time in D_2 - so called negative result experiment. So we conclude that the signal in ORF will have the same relative probability as in MRF. Such kind of the

measurement means obviously the reduction of $\Phi(R)$ in MRF and futher measurement of Φ will coincide with it. Because of it proceeding further we'll assume always the results for the quantum ensemble of observers O without additional refering. As we have no reason to assume that transition from MRF to ORF which we'll call Q-transformation can transfer pure states to mixed ones we must conclude that that this distribution is defined by neutron wave function in ORF. After it we can regard d_d as the variable which describe in ORF the space coordinate distribution of neutrons which constitute pointlike beam in MRF and that it will be the same as the O space distribution in MRF. Probability calculated in MRF for the neutron absorbtion in D_o is :

$$P(d_d) = \sigma_n |\psi_d(x_s)|^2 = \sigma_n |\psi'_n(d_d)|^2 \tag{4}$$

where σ_n is the neutron absorbtion in D_0 cross section. It means that the result of measurement in ORF is also described by QM Reduction postulate, i.e. that initial state during the measurement by RF detector evolve into the mixture of measured observable eigenstates. It's especially important because in general case it'll result in complicated correlations in density matrix of final state. This results demonstrate that if in MRF O wave function have the average x dispersion a_O then from the 'point of view' of observer O any object localised in MRF is smeared with the same RMS a_O.

After considering this qualitative picture we turn to the calculations of more general situations. First we consider the case when n distribution in MRF isn't pointlike but is described by the arbitrary wave function $\psi_2(r_2 - r_0, t)$ and O distribution is given by $\psi_1(r_1 - r_0, t)$. We regard that all the objects evolution including M_R are described by free SE and in its description we can neglect by the internal degrees of freedom of each object. The total system Hilbert space is denoted as H_s, and r_i are 3-vectors. We must find operator (functional) of ψ_2 unitary transformation to ORF

$$\psi'_n(r_2 - r_1, v) = \hat{U}_Q(\psi_1)\psi_2(r_2 - r_0)$$

where v mean all other degrees of freedom it can depend. If to compare it with $\hat{U}_G$ - operator of inhomogenious Galilean transformations which has 6 degrees of freedom $(\vec{v}, \vec{a})$, $\hat{U}_Q$ will have formally infinite number of them defined by ORF state vector ψ_1. Due to it the n wave function in ORF ψ'_n will acquires complicated entangled form which will be calculated transforming space coordinates r_i to Jacoby coordinates which transfer also our 3-particles system state [10]. We'll use 2 sets of them u^0, u^1 corresponding to observers of MRF and ORF :

$$u^0_1 = r_2 - r_0, u^0_2 = r_1 - \frac{r_2 m_2 + r_0 m_0}{m_0 + m_2}, u^1_1 = r_2 - r_1, u^1_2 = r_0 - (r_1 m_1 + r_2 m_2)/M_2 \tag{5}$$

where $M_2 = m_1 + m_2$. We don't include R_c in this sets and regard it as additional system coordinate. Note that to each u^i_j corresponds Hilbert subspace H^i_j of H_s. Due to independence of O and n states in MRF we calculate n wave function in ORF which is in the same time is the system wave function :

$$\psi'_n(u^1) = \psi'_s(u^1) = \hat{U}_Q(\psi_1(u^0))\psi(u^0_1) = \psi_1(u^1_2 + \frac{m_2 u^1_1}{M_2}) * \psi_2(u^1_2 - \frac{m_1 u^1_1}{M_2}) \quad (6)$$

State vector ψ'_n formally is the tensor product of two state vectors which belong to subspaces H^0_1, H^0_2. This transformation is equivalent to relative cordinates axes rotation in H_s defined by $u^0_i = c_{ij}u^1_j$ relation as following from (5). Note that the result doesn't depend on m_0 ,which as will be shown differ from the general situation when n and O states are correlated.

Now we'll account for dependence on m_0 which is also important for the description of the system evolution. The most simple way to perform it is to introduce additional (dummy) observer O_A which mass is very large and relative to which the new system wave fuction $\psi_s(r_0, r_1, r_2)$ is defined. It satisfy to free Schrodinger equation for this 3 objects and can be factorised into $\Phi_c(R_c, t)\psi'_s(u^j, t)$. This equation includes m_0, m_1 mass symmetrically, and if to extract from it c.m. movement accounted by $\Phi_c(R_c, t)$ we'll get the equation for the relative movement M_R, O and n. The choice of observer is equivalent of the choice of u^j set. Note that by no measurements of M_R, O or n Φ_c can be defined by either of MRF and ORF observers. Hence ψ'_s is independent of R_c and defined by the internal evolution of this system. The resulting equation for $\psi'_n = \psi'_s$ the wave function in u^1 coordinates is :

$$-\sum_{j=1}^{N-1} \frac{\Delta_u}{2\mu_j}\psi'_s(u^1, t) = i\frac{d\psi'_s}{dt}(u^1, t) \quad (7)$$

where in this case N=3, $\mu_1 = (m_1^{-1} + m_2^{-1})^{-1}$, $\mu_2 = (M_2^{-1} + m_0^{-1})^{-1}$,$\Delta_u$ is Laplasian of u^1. Now we can annihilate dummy observer O_A ,because obtained equation for internal coordinates doesn't depend on its presence.

In general equation (7) with $3(N-1)$ degrees of freedom $u_1, ..., u_{N-1}$ for N objects including observer l ($l = 1$ in a regarded case) can be regarded as the true QM evolution equation which account the quantum movement of finite mass observer, neglected in Schrodinger equation. C. m. movement of the whole system is logically absent in it ,because it's equivalent to observer absolute movement which can't have physical meaning. In this equation which deals only with the relative movement of the objects and observer we formally can define any object j of N as observer , changing correspondently the u coordinates set. Formulaes for u set for arbitrary N and l can be deduced easely from Hamiltonian invariance under Jacoby transformations [10]. When $m_l -> \infty$ equation (7) transforms to Schrodinger equation for $N-1$ objects. Formally we can approximate N to the number of the objects in the universe, and regard ψ'_s as its wave function ,demonstrating that no preferable RF in the universe exists.

In this framework the most general type of system Q-transformation is when we'll have N_o observers and $N - N_o$ 'particles' described by the wave function $\psi'_l(u^l, t)$ of Jacoby coordinates in RF l. The transformation from RF l to j is transformation of Jacoby u^l set which change state vector $\psi'_j = \hat{U}_{jl}(\psi'_l)\psi'_l$. Considering the group properties of Q-transformations we note that it's finite group of the dimension N_o

,for which existence of unit element is obvious. The inverse element of $\hat{U}_{jl}$ is $\hat{U}_{lj}$. Any arbitrary transformation is expressed in l basis : $\hat{U}_{km} = \hat{U}_{lm}\hat{U}_{kl}$.

Now we turn to calculations for $N = 3$ and ψ'_n of (6), because they have simple physical interpretation. As follows from Schmidt theorem ψ'_n can be decomposed at $t = t_0$ [11]

$$\psi'_n(u, t_0) = \int f(k)\varphi_1(k, u_1^1)\varphi_2(k, u_2^1)d^3k \qquad (8)$$

where φ_1,φ_2 can be chosen so, that they form ortonormal systems in H_1^1 ,H_2^1. For time $t > t_0$ ψ'_n will conserve initial entangled form with the weights $f(k)$ and functions $\varphi'_1(k, u_1^1, t)\varphi'_2(k, u_2^1, t)$ to be solutions of equations (7) with (6) as the initial values. Probability to find some u_1^1 value in ORF is to be :

$$P(u_1^1, t) = \int |f(k)|^2|\varphi'_1(k, u_1^1, t)|^2 d^3k \qquad (9)$$

This entanglement is the consequence of quantum correlations of n and O with M_R expressed by ψ_2 and ψ_1, which results in correlations between n and M_R, analoguous to the proton-electron correlations in hydrogen atom. This results don't mean that all the pure states in ORF are entangled with M_R state. For example if n was emitted by O itself then ψ'_n will depend on $x_2 - x_1$ only and will be disentangled from the M_R state in ORF. In this simpliest case we must take $N = 2$ in (7) and as the result ψ'_n will depend on u_1^1 observable. To calculate the change of state (8) due to the measurement of u_1^1 by ORF we calculate Density Operator of reduced state [11] :

$$\rho_o(u_2^1, u_2'^1, t) = \int \psi_s(u_1^1, u_2^1, t) * \psi_s^*(u_1^1, u_2'^1, t)du_1^1$$

So the measurement transfers pure entangled state into partly mixed state which stay to be pure for u_2^1 , i.e. for r_1 or r_2 observables.

As the example we'll take ψ_1 ,ψ_2 at t_0 to be gaussians with the RMS a_1,a_2 ,the distance between their centers $\vec{d}$ and n moving with the velocity $\vec{v}$. We perform the spectral decomposition by the Fourier transformation on u_2 and take momentum p_2 as the decomposition parameter k.

$$\psi'_n(u, t_0) = \int f(p_2)g(p_2, u_1)e^{ip_2u_2}d^3p_2 \qquad (10)$$

It follows that (vector products can be easily identified):

$$f(p_2) = c_0 * exp[a_1^2\sigma^{-2}(im_2vd + idp_2 - a_2^2(m_2v + p_2)^2)],$$

$$g(p_2, u_1) = exp[i(bp_2 + \frac{vm_2a_2^2}{\sigma^2})u_1 - \frac{(u_1 - d)^2}{\sigma^2}],$$

where $\sigma^2 = a_1^2 + a_2^2$, $b = M^{-1}\sigma^{-2}(m_2a_2^2 - m_1a_1^2)$ and c_0 is normalisation constant. Corresponding time dependent functions are:

$$\varphi'_1(p_2, u_1, t) = \frac{1}{(1 + it'\tau^{-1})}exp[\frac{-(u_1 - d)^2 - 2iv_p(u_1 - d)\tau - iv_p^2\tau t'}{\sigma^2(1 + it'\tau^{-1})}] \qquad (11)$$

$$\varphi_2'(p_2, u_2, t) = exp(ip_2u_2 - \frac{ip_2^2}{2\mu_2}t')$$

where $t' = t - t_0$, $\tau = \mu_1\sigma^2$,$v_p = (\mu_1\sigma^2)^{-1}(bp_2\sigma^2 + vm_2a_2^2)$. Despite the complcated form of ψ_n' it easy to show that the probability distribution (9) of n space coordinate in ORF $r_2' = u_1$ will have gaussian form with RMS

$$\sigma(t) = \sigma(1 + \frac{t'^2}{\tau^2})^{\frac{1}{2}}$$

Note that even if the initial state is factorised into $\psi_1 * \psi_2$ the final state become entangled and depend on m_0. If a_2 is very large and so ψ_2 tend to a plane wave it transforms into the wave packet with average momentum m_2v and constant u_1 probability distribution. Note that if $m_0 >> m_1, m_2$ wave functions (9) don't depend on m_2 at all, conserving initial smearing σ. Note that even if $m_0, m_1 -> \infty$ it follows from (6) that one observer O can be smeared in the RF of the other and vice versa. It's scale is defined mainly by the initial function ψ_d and here we touch the problem of the QM classic limit, where they are also involved. We don't plan to discuss it, stressing only the point that some observables which initially can satisfy this limit at larger time can violate it as well. We can tell that exact Q-symmetry is spontaneously broken by initial cosmological conditions, when a short after Big Bang all particles were closely correlated in space, but this symmetry slowly restores with the time.

As follows directly from (11) if a_1 is currently very small Q-transformations will practically coincide with Galilean space translations ,but they principally differ when a_1 is large i.e. of the order of macroscopic scale . Especially significant it becomes when ψ_1 approach to the plane wave limit. Then all localised in MRF objects in ORF will be described by the wave packets with constant u_1 probability distributions. In general qualitative distinction from Galilean transformations is that under Q-transformations space point isn't transformed into another point , but into a function on 3-space which is reflected by the change of $\delta(r)$ under Q-transformations in (4) and (8). To find the relations between Q- and Galilean transformations $\hat{U}_G$ we can calculate systems state for several dummy observers O_i moving with the different velocities $\vec{v_i}$ and with space shifts $\vec{a_i}$. But the extracted wave function of internal coordinates $\psi_s'(u^1, t)$ doesn't depend on this parameters ; , only $\Phi_c(R_c, t)$ which is nonessential for internal observers will depend on them according to standard Galilean transformations [10]. So we conclude that $\hat{U}_Q$ represents the internal symmetry relative to Galilean transformations and formally they commute. Other properties which should have this newly defined space-time like a continuity,differentiability follows from this properties of the initial space-time and smoothness of wave functions used as the transformation kern [4]. Note that Q-transformations conserve cannonical commutation relations of q, p operators, fundamental for any Field Theory.

Relations and especially commutativity of Q-transformations and Poincare group is to be analysed in the framework of relativistic analog of equation (7) on which we work now. The main idea is the same : to separate c. m. quantum movement and relative movement of the system parts ,but to perform it in relativistic case

is much more complicated task [12]. In this case the objects relative movement is defined by their invariant mass square s. Omitting simple considerations analoguous to described above we get equation of the motion for $N = 2$:

$$- [m_1^2 + m_2^2 + 2m_1(m_2^2 + \Delta_u)^{\frac{1}{2}}]^{\frac{1}{2}} \psi'(u_1^1, t) = i\frac{d\psi'}{dt}(u_1^1, t) \tag{12}$$

The use of relativistic square roots operators is described in [8]. It's easy to see that in nonrelativistic limit this equation coincide with (7) after M_2 subtraction. For $N > 2$ this equation will acquire complicated form expressed through the hierarchy of subsytems each characterised invariant mass operator depending of relative momentum of susbsystem constituents.

In relativistic case we don't expect significant changes of our previous conclusions, because there is a preferable reference frame in this problem which have average velocity of O in which we can define ψ'. Moreover we consider in fact infrared limit for macroscopic object, so the role of negative energy states must be small. Note also that wave function $\delta(x)$ under Lorentz transformation acquire space smearing analoguous to our results [12] .

Now we'll discuss briefly the technical feasibility of the experiments with observers wave packets. We'll consider set-up analoguous to already described above GEO where no gravitation exists in a free fall vacuum chamber and the solid state detector-recorder initially rigidly fixed in solid fixator is released at $t = 0$. After some time period its displacement is defined by the marker particles beam. As the detector-recorder system in fact can be used any detector with the memory like photoemulsion which have coordinate accuracy of the order .1 micron. Especially attractive seems to be plastic or crystall track detectors which under electron microscopic scanning can in principle define the position of dislocation induced by particle track with the accuracy up to several interatomic distances. The same order will have the initial packet smearing a_0, because it's defined by the surface effects between detector and fixator surfaces which extended to interatomic scale. If we suppose the mass of the detector to be 10^{-10} gramm (the mass of emulsion grain which acts as the elementary individual detector) and a_0 value $10^{-2}mk$ we get the average centre mass deflection of the order .1 mk for the exposition time 10^6 sec i.e. about one week. Despite that the performance of such experiments will be technically extremally difficult it's important nonethereless that no principal prohibitions for them exist.

3 Concluding Remarks

We've shown that extrapolation of QM laws on the macroscopic objects demands to change the approach to the space-time coordinate frames which was taken copiously from Classical Physics. It seems that QM permits the existence of the RF manifold, the transformations between which principally can't be reduced to Galilean or Lorentz transformations. This new global symmetry means that observer can't measure its own spread in space, so as follows from Mach Principle it doesn't exist.

The physical meaning have only the spread of relative coordinates of OS and some external object which can be measured by OS or other observer.

Historically QM formulation started from defining the wave fuctions on Euclidian 3-space R^3 wich constitute H_s. In alternative approach we can regard H_s as primordial states manifold [4]. Introducing particular Hamiltonian results in assymmetry of H_s which permit to define R^3 as a spectrum of the continuous observable r which eigenstates are $|r_i>$. But as we've shown for several quantum objects this definition become ambiguous and have several alternative solutions in H_s.

At first sight Q-transformation will violate locality principle,but it's easy to see that it holds for each particular RF, despite that point in one RF doesn't transforms into point in other RF.This is easy to see for nonrelativistic potential $V(r_2 - r_1)$,but we can expect it true also in relativistic Field Theory. So we can suppose the generalisation of locality principle for Q-transformations, which yet must be formulated in a closed form.

In our work we demanded strictly that each RF must be quantum observer i.e. to be able to measure state vector parameters. But we should understand whether this ability is decisive property characterising RF ? In classical Physics this ability doesn't influence the system principal dynamical properties. In QM at first sight we can't claim it true or false finally because we don't have the established theory of collapse. But it can be seen from our analysis that collapse is needed in any RF only to measure the wave functions parameters at some t. Alternatevely this parameters at any RF can be calculated given initial experimental conditions without performing additional measurements. It's quite reasonable to take that quantum states have objective meaning and exist independently of their measurability by particular observer,so this ability probably can't be decisive for this problem. It means that we can connect RF with the system which doesn't include detectors ,which can weaken and simplify our assumptions about RF. We can assume as most important for RF is to reproduce space and time points ordering and record it ,as solid states like crystalls can.

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